Methodology for Assessing Regional Economic Impacts of Charges for Heavy-Goods Vehicles in Spain

An Integrated Approach Through Random Utility-Based Multiregional Input–Output and Road Transport Network Models

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An integrated approach composed of a random utility-based multiregional input–output model and a road transport network model was developed for evaluating the application of a fee to heavy-goods vehicles (HGVs) in Spain. For this purpose, a distance-based charge scenario (in euros per vehicle kilometer) for HGVs was evaluated for a selected motorway network in Spain. Although the aim of this charging policy was to increase the efficiency of transport, the approach strongly identified direct and indirect impacts on the regional economy. Estimates of the magnitude and extent of indirect effects on aggregated macroeconomic indicators (employment and gross domestic product) are provided. The macroeconomic effects of the charging policy were found to be positive for some regions and negative for other regions.

The countries of the European Union are progressively implementing interurban road charges on heavy-goods vehicles (HGVs) on the basis of a Eurovignette directive (Directive 1999/62/EC) that was amended in 2011. This directive establishes the legal framework for imposing tolls on HGVs throughout the European Union. This fact has encouraged increasing research in the area to better understand the transportation and economic impacts resulting from the implementation of these charges.

An extensive literature about the methodologies used to assess the impacts of transport policy measures on macroeconomic indicators, such as employment, gross domestic product (GDP), and the consumer price index, exists. However, most of the research already available has specifically focused on particular policies and geographical locations. Until now, no research has dealt with the effects of charges for HGVs on regional macroeconomic variables, such as employment or GDP.

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The authors' research has been directed at filling this gap. To this end, an integrated modeling approach that includes both a random utility-based multiregional input–output (IO) model (the RUBMRIO model) and a road transport network model was undertaken. In the study described in this paper, the RUBMRIO model was applied to study the regional macroeconomic effects of implementation of a distance-based charge to HGVs, as they have been applied to 6,361 km of highways linking the capitals of the various regions of Spain. The results come from a comparison of a base case scenario, in which no charge is imposed, and a scenario in which HGVs are charged.

BACKGROUND OF ROAD CHARGING

Since 1971 the European Union has been trying to establish a policy on pricing for the use of infrastructure. However, strong opposition to this policy both from some member states and from road haulers have stopped the development of such a policy. Eurovignette Directive 1999/62/EC was the first legal step taken toward the application of this policy. The focus of this directive was primarily the establishment of mechanisms for charging haulers fees for infrastructure costs (construction, maintenance, and operation of the infrastructure and the tolling system). The directive has been amended twice, in 2006 and 2011.

The directive established a methodology for all countries in the European Union to calculate such charges for commercial vehicles with loads of more than 3.5 tons in the Trans-European Transport Network and on other roads to which traffic can be diverted by 2012. However, member states can exempt trucks with loads that are less than 12 tons from making such payments if the fees would produce significant adverse effects or if the transaction costs would be higher than 30% of the revenues produced. Member states are free to impose fees for the use of roads other than roads on the Trans-European Network. The procedure defined for the directive calculates the fees on the basis of infrastructure and environmental costs.

Some countries have already adopted this approach. Switzerland, even though it is not a member of the European Union, has been charging HGVs with loads greater than 3.5 tons on all its roads since 2001. A few years ago, Austria and Germany moved to a distance-based charging approach for HGVs with loads of greater than 12 tons. Recently, the Czech Republic and Slovakia have also adopted similar approaches. Many other countries in Europe, such as France and Poland, are following the same approach (*1–3*).

At the time of this writing, the government of Spain was studying the implementation of charges for HGVs. A study that applied the calculations of the Eurovignette directive to the case of Spain showed that the average charge to HGVs applicable in Spain was €0.079/km (US$ 0.156/mi in 2012 dollars) (*4*). This charge is used for the macroeconomic impact analysis conducted in this paper.

INTEGRATED APPROACH FOR MACROECONOMIC ASSESSMENT OF TRANSPORT POLICIES

Background

Although much research on different methods for assessing transport policies has been conducted, the impacts on the macroeconomic aggregates of charges for HGVs at the regional level have rarely been studied because of insufficient data and unsuitable methodologies (*5, 6*).

Adequate and high-quality impact assessment models are needed to overcome the weaknesses of the typical transport modeling approach. In this regard, several national models (i.e., SAMGODS, ASTRA, NEMO, WFTM, the Italian Model, TEM, REGARD, SMILE, SCENES, STREAMS, and NEAC) have been developed in Europe. These models are used for forecasting, policy simulation, and project evaluation, rather than prediction of future travel patterns and demands under the predict-and-provide principle, which entails the provision of infrastructure according to increases in demand [more details are presented elsewhere (*7–9*)]. Other approaches have been proposed in the United States. For instance, the economic impacts, route flows, and link flows that would occur after disruption of a transportation network because of a catastrophic earthquake were estimated through the use of a combined model of a transportation network and IO relations solved by linearization of the transportation cost term through application of the Evans algorithm (*10, 11*).

All of the practical models available have been developed by consideration of IO economic relationships, systems dynamics models, or spatial computable general equilibrium models. These models address specific issues in freight transport identified previously, such as (*a*) formation of economies of scale, (*b*) representation of logistics features and operations within the transport chain of a shipment, and (*c*) the specificities of the spatial and technical structures of the industry and the requirements for trade (*12*). The proposed model seeks to understand spatial and economic relations by analysis of both output–supply and input–demand relationships through the use of the trade flow patterns among regions. For this reason, the modeling approach used here is based on a combination of two models that are initially used separately. Both the RUBMRIO modeling approach (Figure 1*a*) and a road network model (Figure 1*b*) are considered.

RUBMRIO Model

The IO framework has been a valuable tool for macroeconomic studies since it was first introduced by Leontief in the 1930s (*13*). The standard IO approach has been used in several economic analyses to estimate short-term effects of exogenous impacts (e.g., oil price shocks, technological shocks, and financial shocks). Extended IO models that include other variables (i.e., social and environmental costs) have estimated the policy impacts derived from those variables.

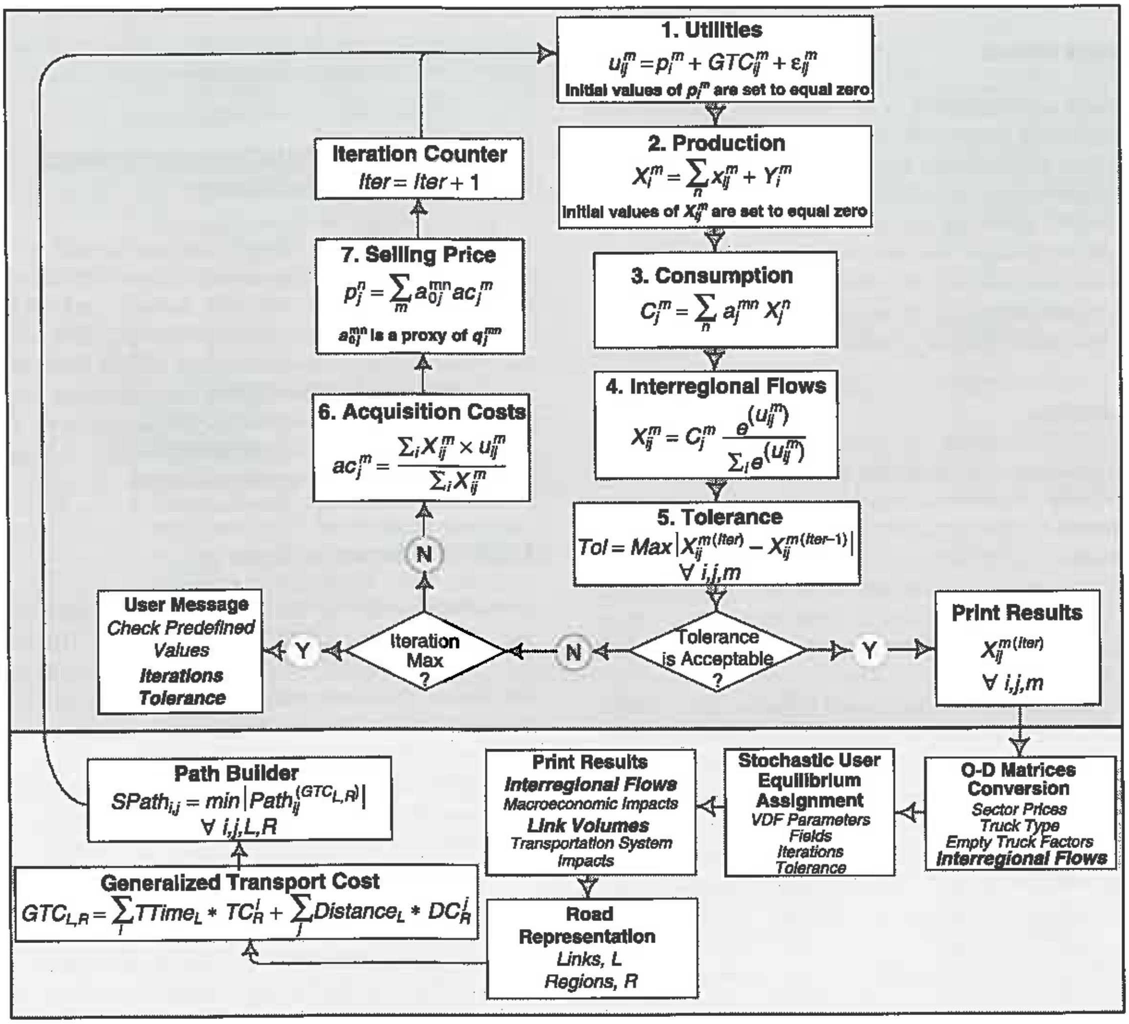
Although the IO approach has commonly been applied to analyze the national economy, which is considered to be a homogeneous unit, it can also be applied to spatial scales that represent trade patterns between regions (*14*). Multiregional IO (MRIO) tables characterize the economic relationships between the regions of a country (*15*).

An MRIO table may be used to estimate the macroeconomic impacts of transport policy measures through the use of sector interdependencies and regional relationships expressed by means of both trade and technical coefficients. Trade coefficients state the share of demand in a region satisfied by production in another region, and technical coefficients describe the input requirements per unit of production in a specific sector. MRIO tables address spatial patterns of economic activity using demand functions for their spatial distribution (*16*). This dependency may be pursued through the introduction of random utility-based models (the RUBMRIO model) to represent trade coefficients. Indeed, trade coefficients simulate the choice of supply region because they show the probability that a product of sector m destined to be consumed within region j will have been transported from production region i.

Some researchers have included rail and road transport in the utility function through the use of a nested logit (NL) model (*17–19*), and others have considered regional differences by including a dummy border variable to better approximate reality in these models (*20*). An NL model was adopted in the present study to estimate the choice of destination regions through the use of two nests.

Analyses with the RUBMRIO model have been performed in combination with well-known land use models involving spatial economy [e.g., MEPLAN, TRANUS, and PECAS (*21*)]. The RUBMRIO model has also been used for analysis of transportation policies to overcome the weakness of the typical travel demand modeling approach. Existing applications of the RUBMRIO model to transport policy measures analyze different topics ex ante, such as the construction of corridors as part of new road infrastructure, changes in travel times, transport investments, operational cost variations, fuel taxes, changes in trade patterns, and regional transport conditions [more details are presented elsewhere (*19, 20, 22–25*)]. These applications have found that transport policies have important indirect effects on various aggregate macroeconomic indicators at the regional level. However, most of these applications do not address direct effects on the transportation system (e.g., congestion reduction, time savings, traffic deviation, pollution, and emissions reductions). Therefore, the transport network model is used to address these effects. A more detailed discussion of the transport network model is provided later in this paper. The relationships of substitution and complementarity between regional areas requiring transport services are assessed by consideration of the prices of products in various sectors because of changes to the infrastructure of a road transport network.

The sector's price in previous developments has been determined through the use of an iterative single fixed-point algorithm that defines a sole spatial equilibrium solution. Main assumptions about the procedure are extensively described elsewhere (*26*). It has also been recognized that feedback on congestion can be obtained by conversion of monetary flows from the IO table to vehicle flows and assignment of these to the transport network to provide new travel times to update costs (*19*). A RUBMRIO model solution that uses a double fixed-point formulation and that considers the introduction of new feedback into the model has been proposed (*20, 27*). The conditions under which a solution is allowed and the uniqueness



(a)

Step 1) Estimation of the utility (u_{ij}^m) for origin region i of moving goods of sector m to be consumed in region j, considering the generalized transport cost (GTC_{ij}^m), initial values of the purchasing prices (p_i^m) in the origin region i are set to equal zero, and a random error term (ε_{ij}^m).
Step 2) Regional production of any given sector m in a producer region i (X_i^m) is evaluated, including intermediate demand (x_{ij}^m - endogenous) and final demand (Y_i^m - exogenous). Initial values of interregional flow of goods and services x_{ij}^m are set to equal zero.
Step 3) Consumption of sector m in region j (C_j^m) is calculated considering the set of technical coefficients (a_j^{mn}) for the production process of all sectors considering region j and total production (X_j^n).
Step 4) Interregional flows (X_{ij}^m) are distributed considering utility variations.
Step 5) The tolerance criterion is evaluated. In the case of achievement the procedure stops, and these interregional flows are the inputs for the road network model.
Step 6) If tolerance was not achieved, acquisition costs (ac_j^m) are updated to represent the average weighted cost of commodity m in region j.
Step 7) New prices (p_j^n) are computed considering technical coefficients without import considerations (a_{0j}^{mn}) as a proxy for the quantity of sector n needed for the production of one unit of sector m in region j (q_j^{mn}) and acquisition costs. These new prices are used to run a new iteration until the equilibrium of interregional flow is achieved.

(b)

FIGURE 1 Integrated approach for macroeconomic assessment: *(a)* RUBMRIO algorithm and *(b)* road transport network model ($SPath_{i,j}$ = shortest route between locations i and j; $TTime_L$ = travel time to reach L; TC_R^i = time cost per minute; DC_R^i = distance cost).

of the double fixed-point approach have been considered, and the uniqueness of the solution is being evaluated.

Road Network Model

The road network is made up of a set of nodes and links. Links represents the physical structure over which the traffic stream moves, including attributes such as length, travel time, speed, number of lanes, and traffic flow restrictions. As highlighted previously, these elements provide an advanced model that can represent complex scenarios with which to model multimodal transportation networks, impedances, restrictions, and a hierarchy for the network (*28*). The nodal points have attributes such as the origins and endpoints of the roads and identification as a regional capital, a larger municipality, or a port.

Model Capabilities

The model should deal with the spatial representation of transport flows on a road network with consideration of two main components. First, the transport cost builder defines the shortest route between any two locations i and j ($\text{SPath}_{i,j}$) through a minimization criterion (e.g., of length, time, and cost). In the path builder, the route is selected if and only if the criterion for reaching the destination node (D) from an initial origin node (O) through links (L) of the transport network layer is the minimum.

Second, the assignment procedure is used to predict the traveler's choice of routes in the road transport network. In this case, the model considers the fact that link travel times are flow dependent. A volume–delay function (VDF) should be considered to reflect traffic behavior, as shown in Equation 1. This traditional formulation was proposed by the Bureau of Public Roads in 1964 and since then has been used to specify how sensitive network times are to traffic congestion.

$$T = T_o \times \left[1 + \alpha\left(\frac{v}{c}\right)^{\beta}\right] \tag{1}$$

where

T = travel time,
T_o = free-flow travel time,
v = traffic volume,
c = practical road capacity, and
α and β = Bureau of Public Roads parameters defined by link type (usually 0.15 and 4, respectively).

These parameters facilitate the adoption of different functions for different kinds of links and for each class of traffic. The practical road capacity (c) is generally used to mean the maximum possible flow of vehicles that can be allowed on a road section per time period (usually 1 h). However, this time period could also specify another situation (e.g., the morning peak period, the midday period, and the evening peak period). Most travel demand models normally use time-of-day factors to distribute trips according to specific time periods to reflect the peak period traffic behavior [see, for example, the models for New York, southeast Florida, and Indiana (*29–31*)].

Model Integration

From the road transport network, the shortest-path routes among regions were computed to generate input into the RUBMRIO model. Once the algorithm reaches equilibrium, origin–destination (O-D) matrices are created. These O-D matrices for each economic sector are assigned to the road transport network to determine traffic volumes on the road network links that enable calculation of macroeconomic impacts and impacts on the transportation system.

CASE STUDY: DISTANCE-BASED CHARGE FOR MOTORWAY NETWORK

In Spain, road freight transport plays a key role in the economic system since it is by far the prevailing mode. Official statistics indicate that 1,567 million tons (97% domestic and 3% international) was transported by road in Spain in 2010 (*32*). Rail freight transport amounted to only 21.44 million tons (*33*). In the domestic market, the dominance of road transport is even greater for domestic freight traffic, reaching a market share of 99% within Spain. The impact of freight rail transport on the domestic market is negligible. For this reason, rail is not considered in the model.

RUBMRIO Model of Spain

To build the model, the existing interregional IO table for 2007, which includes 18 regions and 26 sectors, was used. This table was built for a research project (Desarrollo de Metodologías de Evaluación del Impacto Económico del Sistema de Transportes Mediante Tablas Input–Output Interregionales) and represents multiregional and multisector monetary flows (*34*). A simplification procedure was developed to aggregate sectors and to discard multisector relationships among sectors (m to n) to obtain an MRIO. The final number of sectors considered was 18, of which 9 were freight transport-intensive sectors according to the national freight transport survey (*35*), and 9 were non–freight transport-intensive sectors, as shown in Table 1.

An NL model considering the choice of regions in two relevant nests (region and other) and four relevant alternatives (same, close, near, and far) was adopted and is presented in Equation 2. This NL structure was used as a way to overcome problems detected in the single-level multinomial logit formulation. Rail was not included in the model because, as mentioned earlier, its share for domestic freight transportation is very low in Spain (*36*).

$$u_{ij}^{m} = -p_i^m + \lambda^m \ln\left[\sum_R \exp\left(u_{ij,R}^m\right)\right] \tag{2}$$

$$u_{ij,R}^{m} = \beta^m \text{GTC}_{ij,R}^m \tag{3}$$

where

u_{ij}^m = utility of acquisition of commodity m in region i and transport of commodity m to region j;
$u_{ij,R}^m$ = systematic utility of lower nest, where R represents a specific region;
p_i^m = price of goods or services of sector m in region i;
λ^m and β^m = logit model parameters; and
GTC_{ij}^m = generalized transport cost (GTC) of sector m goods from production or origin region i to consumer region j.

The total GTC between production and consumer regions was considered to avoid possible multicollinearity in each term of the cost function. For the calculation of transport costs inside the same

TABLE 1 10 Economic Sectors and Estimated Parameters for NL Model

Sector	β	λ	Likelihood Ratio Index
Freight Transport Intensive			
1. Agriculture, fishing, wood, and cork	−0.0036997 (−1.791)	0.6022334	0.1509
2. Food and kindred products	−0.0022116 (−1.618)	0.3980369	0.1737
3. Nonmetal minerals and kindred products	−0.0031048 (−2.469)	1.2123022	0.1738
4. Energy, petroleum, and petroleum products	−0.00359032 (−1.662)	0.2856076	0.1012
5. Mining	−0.00292221 (−2.393)	0.9987490	0.3280
6. Metal minerals and kindred products	−0.00261765 (−1.942)	0.7592084	0.1227
7. Construction	−0.00362973 (−2.508)	1.7298120	0.3650
8. Chemical and allied products, paper, edition and kindred products, and rubber materials	−0.00186099 (−1.726)	0.5344023	0.1664
9. Textiles, clothing, leather and shoes, industrial machinery and equipment, electric and electronic equipment, transportation equipment, and other manufacturing industries	−0.00251822 (−1.68)	0.4169975	0.1436
Non–Freight Transport Intensive			
10. Trade and repairs of vehicles	na	na	na
11. Tourism	na	na	na
12. Transportation and storage	na	na	na
13. Communications	na	na	na
14. Finance and real estate	na	na	na
15. Government services	na	na	na
16. Education	na	na	na
17. Health	na	na	na
18. Other nongovernment services	na	na	na

NOTE: Wald statistical significance test values appear in parentheses. na = not applicable.

region (i.e., i equal to j), an average cost was determined from the capital of the region to provinces of that region or points of interest (ports and large municipalities) through the use of the road transport network to facilitate the representation of intraregional costs. GTC_{ij}^{m} is initially computed through the transport network model. A more detailed discussion is provided below in the section on the road network model.

The regions outside continental Spain (i.e., the Canary Islands, Balearic Islands, and Ceuta-Melilla) were linked to the continental transport network through the use of fictitious links, and a larger cost attribute for the fixed cost in the transport network was assumed to diminish the possibility of freight transport by road. This assumption considers that transport costs increase with distance; therefore, the interregional flow of goods from and to these regions is discouraged. The estimated parameters are shown in Table 1.

The NL utility model parameter estimates were obtained by the maximum likelihood method with NLOGIT software. The Wald statistical significance test (values are shown in parentheses in Table 1) shows that some parameters achieved significance of 95% and others achieved significance of 90%. The likelihood ratio test also gave appropriate values for this model application. Low values in these two tests could be explained by the lack of sufficient data at this point and point to the need for more data on transport flows of goods to obtain more precise results, as indicated elsewhere (*37*).

The single fixed-point algorithm solution shown in Figure 1*a* was adopted to achieve a solution for the RUBMRIO model. The tolerance was established to be a value of 0.01 and was reached by use of the algorithm implemented through a macro program based on Visual Basic for Applications in Excel software.

Road Network Model

O-D Matrix Conversion

Conversion factors were applied to convert each trade in the economic sector from monetary units (euros) to tons and tons to numbers of trucks per year, and these figures were expressed as the number of trucks per day. This conversion considered an average price (euros) per ton; the HGV configurations of each sector, because size and weight limits (e.g., bulk, tank, and refrigerated HGVs) can vary; and a factor reflecting the percentage of empty trips of trucks. As acknowledged previously (*38*), separate models for empty trips have been developed to consider this value, which is added to the value for loaded trips to estimate the total number of HGV trips to be used in assignment models. The percentage of empty HGV trucks was adopted from the National Survey of Road Freight Transport by consideration of truck pickup and delivery operations as a proxy (*35*). This information distinguishes between loaded and empty operations, facilitates the identification of the right direction for loaded and empty trips, and offers a good basis for the purposes of the present model because detailed information required to build an empty trip model is not available in Spain. Information from research on external trips (to and from other, peripheral countries, such as Portugal, and elsewhere in Europe) was also incorporated because it was not considered in the RUBMRIO model (*39*).

Road Network

The 2007 road transportation network is depicted in Figure 2. It highlights the motorway that was adopted for use in the case study and that links the capitals of the regions of Spain. The length of the network on which charges are applied is 6,361 km. The road network model was built with TransCAD software. All inputs for each link of the network were defined according to the functional classification of the road, as shown in Table 2. Speed limits for HGVs and capacity targets were adopted from national limits. These values were penalized throughout the consideration of the road slope. Finally, modified VDF curves with different coefficients and exponents for each functional classification class were used. A relatively steeper curve was defined for toll highways, given that this class should be constrained to a higher degree than motorways or highways and national roads. The final calibrated parameters are shown in Table 2.

Furthermore, traffic count data for passenger cars, buses, and HGVs on each link were also included. These data were taken from *Mapa de Tráfico 2007* to be used as preload traffic and to validate the assignment model for the base-case year (*40*).

Shortest-Path Cost Builder

Links are characterized by time and length. To incorporate these variables into the decision-making process, a GTC function was defined for each link according to regional location and Equation 4. This linear function represents the total cost attributed to each link when it is reached.

$$\mathrm{GTC}_{L,R} = \sum_i \mathrm{TTime}_L * \mathrm{TC}_R^i + \sum_j \mathrm{distance}_L * \mathrm{DC}_R^j \tag{4}$$

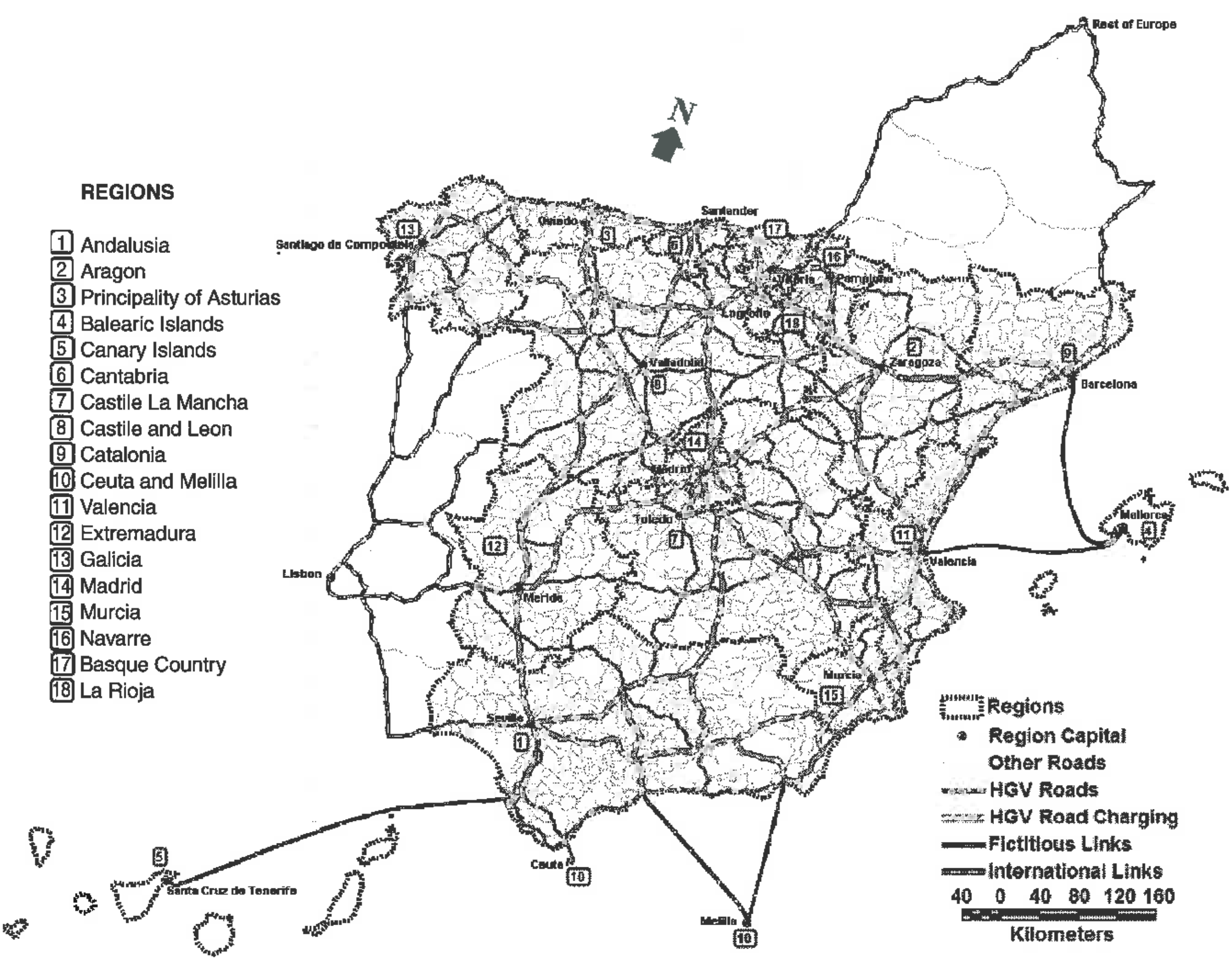


FIGURE 2 Spain's freight road transport network, 2007.

TABLE 2 Input Data for Road Transport Network

Functional Classification Class	Cross Section ($x \times y$)	Speed (km/h) by Terrain			Capacity (PCU/h/lane) by Terrain			VDF Parameters	
		L	R	M	L	R	M	α	β
Toll highways	3×3	100	90	70	2,000	1,800	1,700	2.00	10
	2×2	100	90	70	2,000	1,800	1,700	2.00	10
Motorways	3×3	90	80	60	1,900	1,700	1,500	0.90	4
	2×2	90	80	60	1,900	1,700	1,500	0.90	4
National road system	1×1	70	50	40	1,500	1,300	800	1.00	7

NOTE: PCU = passenger car unit; L = level (0% to 5% grade); R = rolling (5% to 15% grade); M = mountainous (>15% grade); $x \times y$ = number of lanes in each direction.

where

$\mathrm{GTC}_{L,R}$ = generalized transport cost in each link (L) belonging to a specific region (R);
TTime_L = travel time required to reach L;
TC_R^i = time cost per minute, including the cost of labor, financing, insurance, taxes, and other, indirect costs;
$\mathrm{distance}_L$ = distance required to reach link L; and
DC_R^i = distance costs, including fuel, tolls, accommodation, allowances, tires, maintenance, and repair costs (€/km).

The functionality is implemented in TransCAD software through the shortest-path algorithm.

Assignment Model

A stochastic equilibrium assignment procedure was selected to perform HGV traffic assignment. This procedure was chosen because it is frequently used for statewide travel demand models for freight and passenger transportation (*30*). This procedure is also more realistic because it acknowledges individual variations in perceptions of generalized costs. The stochastic equilibrium assignment procedure makes it easier for haulers to choose alternative routes. According to this procedure, less attractive routes are used less but do not have zero flow. The optimal solution is achieved through an interactive method of successive averages, given a convergence criterion.

The VDF function shown in Equation 1 was adopted by use of a time period of 24 h (1 day) because detailed information about time periods was not available. Daily capacity was assumed to be the hourly capacity expanded by a daily expansion factor (*41*).

Calibration and Validation

As indicated elsewhere, the results and demonstration of the calibration are referred to as model validation (*29*). Model validation starts with the most general aggregate verification and progresses toward more detailed volume-related verification (*42*). In general, the root mean square error, the percentage of root mean square error, and the total error are calculated and factored into the analysis. The validation was conducted on the basis of comparisons of predicted and observed flows on links for the base-case scenario with changes in VDF parameters as well as daily expansion factors in an iterative process intended to minimize deviations between assigned and observed traffic flows.

The validation results, depicted in Table 3, show how the targets recommended in the guideline were met by facility type, with lower values for higher-volume roads (i.e., tolled roads and motorways) being considered (*42*). The higher values registered on lower-volume roads, such as those of the national road system, do not exceed target recommendations.

ANALYSIS OF RESULTS

The methodology previously defined enables estimation of the first indicator, employment changes linked to transport policy measures, by the use of the monetary value corresponding to jobs included in the columns of the MRIO table as part of the final payments section for each region.

The second indicator analyzed was GDP, which serves as a good proxy for measurement of the impact of policy measures on the regional economy. For that analysis, the income approach was used.

TABLE 3 Model Validation by Functional Classification Class

Functional Classification Class	Number of Links	Average Traffic Count	Average Error	Percentage of Error	Percentage of RMSE	Recommended Percentage of RMSE
Toll highways	578	5,576	−111.88	−3.65	29.92	43
Motorways	1,776	8,562	129.39	3.57	21.91	37
National road system	1,520	3,547	183.50	19.86	45.55	51
All	3,874	8,523	114.62	4.62	27.95	37

NOTE: Average error = (estimated volume − count volume)/number of links; percentage of error = [(estimated volume − count volume)/number of links] * 100; percentage of RMSE = $\{[\sum_i (\text{estimated volume}_i - \text{count volume}_i)^2/(\text{number of links})]^{0.5} * 100\}/\sum_i \text{count volume}_i/$number of links); the recommended percentage of RMSE targets were calculated for the average traffic count data according to the guidelines in the FHWA guide (*41*); RMSE = root mean square error.

By that approach, all the income earned by firms and households (i.e., employment compensation, net interest, corporate profits, and rent) is computed.

The 2007 MRIO table has more than 21 million jobs and a GDP of €966,889 million. Variations in employment and GDP across regions caused by the implementation of a fee for HGVs are shown in Table 4. Figure 3 provides a graphical display of the changes in absolute terms for both indicators on a regional basis.

The implementation of a fee will mean higher transportation costs. This in turn will produce several effects on the regional economy. First, imports and exports to other regions will be more expensive, so interregional trade will be reduced. The reduction of imports and exports will depend on such factors as the value per ton of commodities. The lower that the value per ton is, the more sensitive that exports and imports will be to transportation costs. Second, regional production will replace imports only if the region is able to produce these goods or services internally (competitive imports can be assumed to be close substitutes), so the net effect will be internal growth in these regions because domestic production means additional direct capital and labor requirements. However, in regions that are not able to participate in regional production, production will end up decreasing and jobs will be destroyed because the sector's commodities that are not produced domestically (noncompetitive imports) will be required. Imports from distant regions will be replaced by imports from closer regions, so the regional employment and growth in the regions of distant suppliers will decrease and the productivity of closer regions and the demand region will be secured.

Application of the methodology outlined in the paper to the policy of implementation of a fee of €0.079/km to HGVs in the selected network shows that the number of jobs would grow by 0.16%, which means the creation of 35,540 new jobs in the various regions of Spain. In addition, the national GDP would increase by 0.07%, which would mean total growth of €673 million.

The results show that the impact at the regional level is quite different depending on the region. The region of Madrid, which is one of the richest ones and which is located in the center of Spain, receives important benefits stemming from the application of fees to HGVs. This also happens in the regions of Catalonia and Valencia, which are also quite rich compared with the average for Spain, even though they occupy a more peripheral position than Madrid. This effect might be caused by the fact that these regions export commodities with a higher value per ton than the average and their imported goods have a lower added value per ton. As a consequence, an increase in transportation costs has a greater impact on imports from other regions than on exports to other regions, which eventually might end up promoting growth and employment in these regions.

The results also show how the poorest and most peripheral regions of Spain (i.e., regions distant from the center, which is taken to be Madrid) also experience job and GDP growth; these regions are Galicia, Andalusia, and Extremadura. This effect is more difficult to explain from an intuitive standpoint. The cause might be that these regions rely on production from within their own region instead of imports from the richest regions. In the case of Andalusia and Galicia, an explanation might be that these are large regions with diversified economies, which allow higher levels of self-sufficiency and higher levels of consumption of the regional output. Other poor regions with less diversified economies experience job and GDP reductions.

TABLE 4 Variations in Employment and GDP Across Regions That Charge a Fee for HGVs

Region	Employment by Scenario		Difference in Employment		GDP by Scenario		Difference in GDP	
	Base Case	Policy Case	No. of Jobs	Percentage	Base Case (€ millions)	Policy Case (€ millions)	€ (millions)	Percentage
Andalusia	3,206,700	3,214,184	7,484	0.23	138,826	138,975	148	0.11
Aragon	681,200	680,133	−1,067	−0.16	30,302	30,281	−22	−0.07
Principality of Asturias	429,500	420,337	−9,163	−2.13	20,773	20,568	−205	−0.99
Balearic Islands	538,800	533,134	−5,666	−1.05	23,763	23,648	−115	−0.48
Canary Islands	889,100	886,339	−2,761	−0.31	37,792	37,738	−54	−0.14
Cantabria	270,100	263,654	−6,446	−2.39	12,081	11,938	−143	−1.18
Castile La Mancha	842,900	824,801	−18,099	−2.15	33,190	32,863	−327	−0.99
Castile and Leon	1,167,900	1,153,168	−14,732	−1.26	52,099	51,772	−327	−0.63
Catalonia	3,851,300	3,876,992	25,692	0.67	179,008	179,549	541	0.30
Ceuta and Melilla	68,700	63,946	−4,754	−6.92	2,769	2,702	−67	−2.42
Valencia	2,248,500	2,281,458	32,958	1.47	92,943	93,567	624	0.67
Extremadura	422,300	427,451	5,151	1.22	16,261	16,355	94	0.58
Galicia	1,211,900	1,235,457	23,557	1.94	49,245	49,691	446	0.91
Madrid	3,463,500	3,480,443	16,943	0.49	169,991	170,354	363	0.21
Murcia	612,300	605,473	−6,827	−1.11	24,591	24,459	−132	−0.54
Navarre	354,000	352,172	−1,828	−0.52	16,298	16,261	−36	−0.22
Basque Country	1,143,400	1,140,041	−3,359	−0.29	59,923	59,842	−81	−0.13
La Rioja	158,400	156,857	−1,543	−0.97	7,035	7,001	−34	−0.48
Total	21,560,500	21,596,040	35,540	0.16	966,889	967,563	673	0.07

NOTE: No. = number.

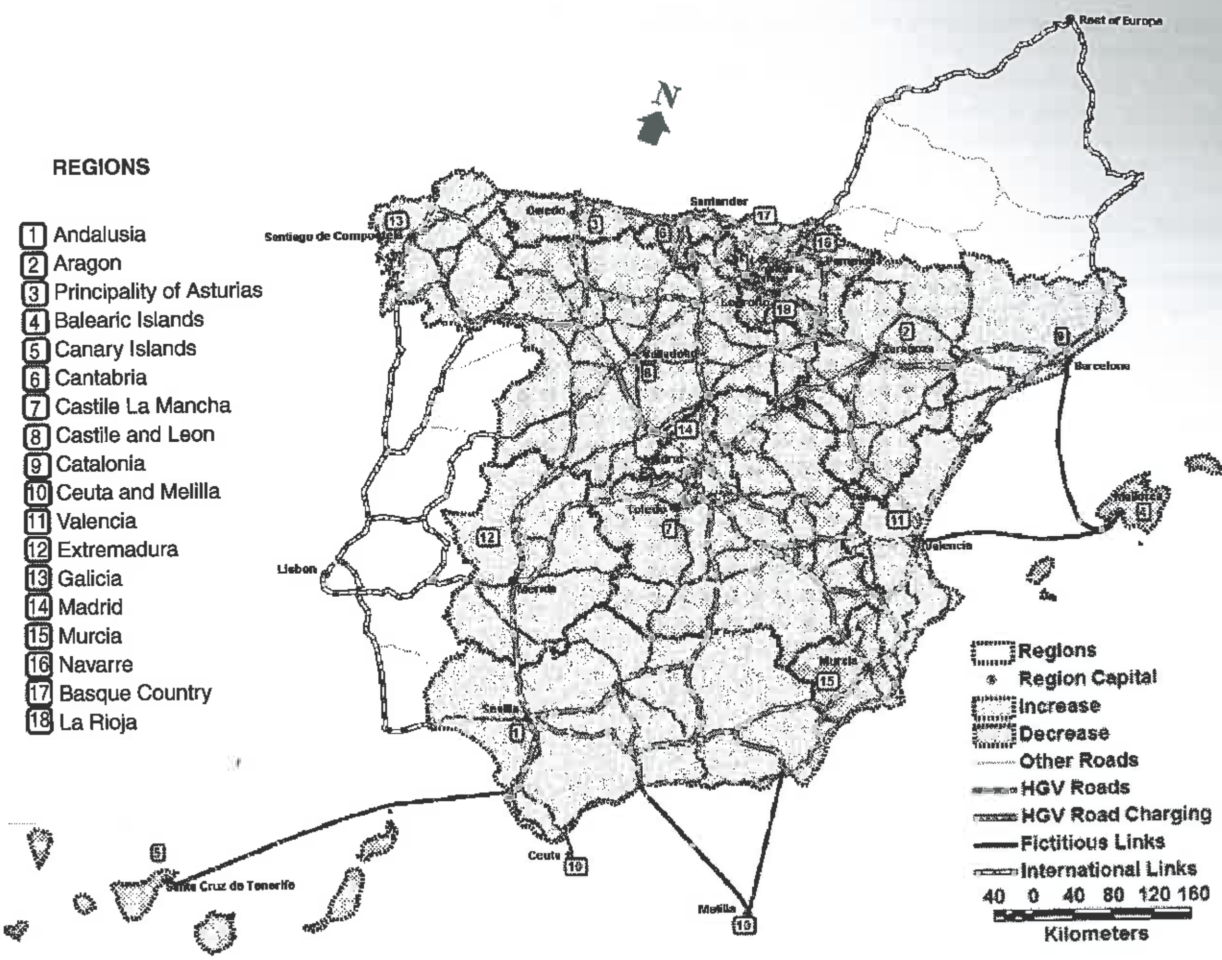


FIGURE 3 Impacts of fees for HGVs on employment and GDP in Spain.

CONCLUSIONS AND REMARKS

The policy of implementation of fees for HGVs has several effects on the economies of the various regions in Spain, and the results of this research also provide evidence that the regional economic structure has a much greater influence on the economy than on location.

These results show that some industries mainly focus on their regional markets because their ability to supply other regions is less with higher transport costs. Although increases in transport costs inhibit interregional trade, the existence of large intraregional markets may offset this effect through increases in intraregional sales. Jobs and GDP variations across the different regions depend on the trade-off between the reduction in exports to other regions and the increase in intraregional sales.

Each region will experience different substitution effects as a result of the policy, which means that some regions will not undergo a negative change but others will. Although regional production will increase for some sectors, it will decrease for other sectors because it may prove to be economically unviable to substitute products from the same region or from other regions. The use of the revenues coming from this fee was not considered in the policy scenario because such a consideration is beyond the scope of this paper.

The comparison of the base case and the charging policy scenarios shows the effect of the policy on the distribution of jobs and the GDP across regions. The regional GDP values from the model are nominal and not real values. To compare real GDP values, the model should consider the increase in prices caused by the implementation of the fee. If real values were compared, the GDP might not increase in the policy scenario.

Although the methodology applied is sophisticated enough to obtain sufficiently reliable results, room for improvement remains. The first set of limitations stems from the current availability of data. It would be desirable to have more detailed data from IO tables for provinces within Spain, which would allow more complete results. The second set of limitations comes from the IO methodology because the model is designed to determine the effects of changes in an economy at a particular point of time but does not permit questions about industrial matters, such as innovation, technological progress, ownership structures, and other factors, to be answered. However, this methodology has depicted structural changes in the IO framework because of the variations in GTCs between pairs of regions through the relocation of trade patterns. Moreover, IO information from other countries will improve the representation of exports and imports because they were considered exogenous in the model. In addition, much more complete information about other transportation modes used in the European Union will enhance the applicability of this approach. In turn, this information will improve the model so that it is able to shape the split of freight between truck and nontruck carriers involved in international trade.

Finally, the results demonstrate that the model developed in this research is able to forecast the impact of changes in nationwide transportation policies on regional economic aggregates.

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